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TECHNICAL DIVISION

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MONTHLY PROGRESS REPORT ON PROJECTS

July 1 - July 31, 1945

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FERCLEVE CORPORATION

TECHNICAL DIVISION

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#67

REPORT FOR PERIOD: July 1 - July 31, 1945

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Reported by: Barnett F. Dodge
Technical Director

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Orrington E. Dwyer
Casper A. Todaro
Group Directors

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TABLE OF CONTENTS

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APPENDIX

PROJECTS UNDER INVESTIGATION

As in the last month's report, only the work of the Progress Development Section is included in this report. The operations of the two assay laboratories of the Division are adequately covered by the weekly reports issued by each laboratory.

A complete list of the projects undertaken by this Division is given below. Some of these projects have been completed and others are inactive at the present time and the projects in these two categories are indicated on the list.

Project No.	Title
1 . . .	Individual Column Performance. Product Assay versus Production Rate
2 . . .	Comparison of Individual Column Performance by the Dole (Rack 9) Method of Product Withdrawal with the Intermittent Method
3 . . .	Measurement of the Rate of Flow of Process Fluid
4 . . .	Equilibrium Studies on Isolated Columns
	(a) Isolated Top Only
	(b) Isolated Top and Bottom
5 (Completed)	Production Rate vs. Assay Studies on Whole Circuits, Using Intermittent Method of Product Withdrawal
6 (Completed)	Cross-Check on Shipment Sample Between M.S. and "Counting Method" Laboratories at Fercleve and Carbide & Carbon, Using Special "Double-end" Sample Tubes.
7 (Completed)	Storage Chamber Depletion Studies
	(a) Effect of Storage Chamber Concentration on Production Rate
	(b) Single Tank vs. Two Tank Method of Material Flow Across Bottom of Circuit
	(c) Determine Schedule for Removal of Depleted Material from Storage Chamber

Project No.	Title
8 (Completed)	Sampling Methods
	(a) Trial Use of 100 "Double-end" Sample Tubes for Product Samples with View to:
	1. Reducing Number of Empty Tubes
	2. Improving Agreement Between Laboratories 1 and 2.
	(b) Study of Reliability of Samples from Tits
9 (Inactive)	Preparation of a Technical Operating Manual
10 (Completed)	Assembly of PVT Data and Thermal Data on Process Fluid in Form for Convenient Use
11 . . .	Stress Corrosion of Nickel Welds
12 . . .	Development of Method of Product Removal by Top Circulation (Rack 9 or Dole Method)
13 (Completed)	Plotting Daily and Accumulative Production Rate vs. Time for 6 Selected Racks
14 . . .	Pressure Measurements
15 (Completed)	Variations in Top Assay Among Columns in a Circuit and Effect of Milking on it
16 . . .	Service Tests of Fittings for Use on Process Fluid
17 . . .	Study of Accuracy of Assay Results from the Two Laboratories
18 . . .	Preparation of a Standard Sample of Product for Comparison of Assays of the Fercleve Laboratories and Outside Laboratories
19 . . .	Tests of Individual Columns in a Circuit Under Non-Milking Conditions
(Completed)	I. Test of Uniformity of Columns in a Circuit
	II. Correlation Between Annular Spacing and Column Performance
	III. Effect of Material Pressure on Column Performance Using 450# Steam
20 (Completed)	Effect of Scale Formation on the Copper Tubes on the Performance of a Column

There was a considerable turnover in personnel of the Process Development Section due both to required release of army enlisted men and to some curtailment of the activities of the Division. Some projects have been completed during the month and no new ones added. At the beginning of the month, the assignment of projects and personnel to the two group leaders was as follows:

Group No. 1

Director, Dr. O. E. Dwyer

Personnel: J. C. Blackwood, W. R. Casto, Wm. B. Daly, Jr. L. Davidson, J. S. DiRende, Mrs. May Farber, W. J. Clossey, S. J. Green

Active Projects: 4, 17, 19, 23, 27, 29, 30, 32, 33, 35, 39

Group No. 2

Director, Mr. C. A. Todaro

Personnel: T. J. Ashford, W. W. Binger, W. J. Clark, Daniel Frishman, R. H. Hill, J. D. Hoffman R. T. Overman, R. C. Shaefer, M. D. Snyder H. Tilp, R. Van Winkle, I. W. Greenberg, H. W. Hoffman, C. F. Sanders, D. K. Taylor

Active Projects: 1, 2, 3, 11, 12, 14, 15, 16, 21, 24, 25, 31, 34, 38, 40

During the month, or in a few cases close to the first of the month, the following were terminated:

J. C. Blackwood
L. Davidson
J. S. diRende
I. W. Greenberg
H. W. Hoffman
R. T. Overman
C. F. Sanders
D. K. Taylor
C. R. Leder
W. Wolkowitz

Mr. H. L. Hemphill was transferred to Laboratory No. 2 but will continue to work on Project No. 22.

New men added to the Process Development Section include R. W. Greenlee, B. Selikson, L. H. Silver, W. Smith. Miss Jean Elliott was added to the secretarial force.

The total number of persons in the Division (as of July 31, 1945) was one-hundred forty-six (146) distributed among the various sections as follows:

Laboratory No. 1	67
Laboratory No. 2	54
Process Development Section	21
Service Group	4
	146

SUMMARY OF MONTHLY PROGRESS REPORTS OF INDIVIDUAL PROJECTS

JULY 1945

Project No. 1 - Individual Column Performance. Product Assay versus Production Rate

No further work was accomplished on this project (six circuits remain to be column tested) during the month of July. High pressure steam supply was limited and very irregular. However, this fact allowed the laboratories the opportunity of catching up on their large back-log of samples. At present, complete results are available on 1089 columns. All columns will be classified by a letter or number. Letters indicate the column is capable of producing better than par material at 100 g.c.d. and numbers indicate an assay of less than par at 100 g.c.d. The per cent of columns in the various assay ranges is as follows:

Classes	Assay Range at 100 g.c.d.	Per cent in this Range
A	Above +12	2.8
B	+9 to +12	4.1
C	+6 to + 9	12.4
D	+3 to + 6	22.8
E	0 to + 3	31.0
I	-3 to 0	19.8
II	-6 to - 3	4.0
III	-9 to - 6	1.8
IV	-12 to - 9	0.7
V	Below -12	0.3

From the data obtained from this project, it is possible to estimate, within 10-15%, the production expected from each circuit (see letter from C. A. Todaro to Dr. B. F. Dodge on July 25, 1945). The plant, as a whole, is capable of averaging 131 gms/col/day at par. The June production averaged 119.26 gcd or 91.03% of expectations. Since our data is slightly low, the average expected production is believed to be nearer 145 g/col/day at par.

Project No. 2 - Comparison of Individual Column Performance by the Dole (Rack 9) Method of Product Withdrawal with the Intermittent Method

As stated in the earlier reports, it has been found that product removal on an individual column by either method gives approximately the same results. The effect of limiting top and bottom circulation is at present being studied. Later we hope to determine the effect of poor columns on the good ones.

The limited steam supply in July prevented us from obtaining any reliable data.

Project No. 3 - Measurement of the Rate of Flow of Process Fluid

Last month's report on this project answered many of the questions concerning flow rates that have puzzled us for many months. During the month of July, this project was considered inactive since more urgent projects were given priority with a limited amount of steam available.

Further work is planned for August in constructing a flowmeter capable of measuring flow rates from 10-60 pounds per hour with a reasonable degree of accuracy. The present meter has an accuracy of less than 6% for flow rates ranging from 2.8 to 7.5 pounds per hour (See May Report). Present flow rates throughout the plant average approximately 7-8 pounds per hour. The cascade systems are using 3-5 convector loops in series with flow rates believed to be in the neighborhood of 25 pounds per hour.

Project No. 4 - Equilibrium Studies on Isolated Columns

Rate-of-rise-to-equilibrium data have now been obtained on 13 columns. They can be divided into the following categories: three exceptionally "good" columns as indicated by results of Project No. 1, six newly-installed columns, and four columns picked at random in the plant. It was found that the new columns performed as well as the three exceptional ones, giving data which indicated production rates well above 200 grams per day at "par" assay. On the other hand, the columns which were picked at random, on the average, showed predicted milking rates about 100 grams per day less than the other two groups. This may indicate that new columns now being installed in the plant are better constructed, or it may mean that they are better conditioned, or both. The number of columns tested to date are too few to draw definite conclusions.

In two cases where milking data were available and where the rate-of-rise data were complete, there was perfect agreement between actual performance and that predicted from rate-of-rise data.

Project No. 9 - Preparation of a Technical Operating Manual

A number of copies of our Technical Operating manual have been issued for use in the Training Program of S-50. The manual was not edited to our satisfaction before issuing. However, due to its urgent need for training operators, it was decided a polished manual was not necessary. Further editing will be done at some future time after the more urgent projects have been completed.

Project No. 11 - Stress Corrosion of Nickel Welds

This project has been very inactive during the month of July. The reasons are as follows:

Project No. 11 - Stress Corrosion of Nickel Welds - Continued

1. Test samples have not arrived

2. Engineering Department is in the process of drawing up details for steel chambers

3. The individuals familiar with the project were on vacation

Project No. 12 - Development of Method of Product Removal by Top Circulation (Rack 9 or Dole Method)

Early in July it was found that five pots of material were on hand that had very low assays. These pots were composed of product milked from all circuits in the S-50 plant that did not meet assay specifications for shipment. It seemed advisable to convert Circuit 1 of Rack #9 to the cascade system and enhance these pots to par on the second bank of the cascade.

It was found that enhancing low assay pots by this method, the two stage system was 35% more efficient than enhancing by the Dole Method (see Project No. 31). By this process we were able to recover, in the most efficient manner, the five pots of low assay material.

At present, no other circuits have product removal by the Dole Method.

Project No. 14 - Pressure Measurements

The pressure recording instruments (both material and steam) were installed in Transfer Room No. 1 and another material pressure recorder was installed on Column No. 31.

Data recorded revealed that steam pressure variations in the storage chambers caused the greatest material pressure changes in the storage chambers and the rack. Only two instances were found in two weeks of observations in which the material pressure changed while the storage chamber steam pressure remained constant. Both of these fluctuations were very minor. Since no steam pressure recorder exists as yet on the rack, the irregularities in rack steam pressure is not known. A recorder is ready to be installed for rack steam pressure and will be installed as soon as the rack is shut down.

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Project No. 16 - Service Tests of Fittings for Use on Process Fluid

It has been found that the needle-type material valves made to date are unsatisfactory due to the fact that the seat is welded to the body. Good alignment is very difficult to obtain. Hence, a valve is being made that has the seat in the body of the valve itself. This is the conventional manner of making valves. A heavier stem and deeper packing space is also being incorporated into the new valve.

An individual column milker has been developed that operates quite satisfactorily when 25 gms or more per column is required to be withdrawn. An attempt is being made to develop an indicator that will quickly determine whether the individual columns have "milked" or not.

A number of adapters have been successfully made for connecting 1/4" copper tubing to a 5/16" nickel tit. These adapters are double-ferruled (compression type, see Dwg-16-6) and hold material very well. Previously an adapter with ferrule fitting at one end and thread to thread seal at the other end, leaked quite frequently at the threaded connection seal. This adapter can be very easily made in large quantities at a very low cost.

Project No. 17 - Study of Accuracy of Assay Results from the Two Laboratories

An analysis of assay results on shipments for the period June 12 to July 5, 1945 showed that the average assay of shipment containers according to Laboratory 1 was 1.197, with an average deviation of 0.013. The corresponding figures for Laboratory No. 2 were 1.189 and 0.009, respectively. These figures are based on two samples per container for Laboratory No. 1 and one sample per container for Laboratory No. 2. The agreement between the two laboratories was not as good for the period stated above as for the previous two or three months.

The precision of Laboratory No. 1 has shown appreciable impairment during the month of June. For details, see report on this project in the Appendix.

Project No. 18 - Production of a Standard Sample of Product for Comparison of Assays of the Fercleve Laboratories and Outside Laboratories

This project was started several months ago at a time when there was a small but significant difference between average results reported by our two laboratories on samples from the same material. Also some differences were noted between our own assay of product shipped to our customers and their assay. To check on these differences it was decided to prepare some standard samples and have them assayed by three laboratories in addition to our own two. Since then, the importance of such a check has diminished considerably and the project has not been pushed. However, some of the results are in and it may be of interest to summarize them as is done in the following table:

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Table 1. Results of Assay of a Standard Sample by Several Laboratories

Laboratory	Method	% Enhancement of light isotopes	Notes
Columbia University	Mass spectrometer	21.30	Av of results on 4 instruments Av. Dev.= 0.38
Carbide & Carbon Chemicals Corporation	Alpha counting	21.2	A.D. = 0.6
"	Fission counting	23.4	A.D. = 1.1
"	Mass spectrometer	21.6	A.D. = 1.4
Fercleve Laboratory No. 1	Mass spectrometer	21.0	A.D. = 0.5% (12 assays)
Fercleve Laboratory No. 2	Alpha counting	21.0	A.D. of 10 results = 0.33

The agreement is excellent with the exception of the fission method, and it is of no practical interest to us. It is especially to be noted that the average results from our own two laboratories are in very close agreement.

Project No. 19-II - Correlation Between Annular Spacing and Column Performance

Performance data on 26 columns show absolutely no correlation between column capacity and average annular space thickness as determined by the water displacement method. For details, see monthly report on this project in the Appendix. Although negative results have been obtained thus far on this project, it is planned to continue the work until a sufficiently large number of columns have been tested.

Project No. 19-III - Effect of Material Pressure on Column Performance Using 450 lb. Steam Pressure

This project was started only recently, and there are no results to report at this time. The purpose of the project is to determine the most efficient material pressure at which it is feasible to operate those racks which use 450 lbs. steam. Five columns on each of the four circuits of Rack 1 are being tested by the rate-of-rise method. The four circuits will be operated at different material pressures varying from 750 to 1900 lbs/sq. in.

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Project No. 21 - Measurement of Annular Space in Columns

It has been demonstrated during the month of July that the average annulus measurements by the Nitrogen Flow Method are reproducible within an error of 0.3%. This is considerably better than last month's precision of 2.2%. It is believed that standardization of operating conditions (temperature, cleanliness, etc.) has brought about this improvement in reproducibility.

Large variations in average annulus (over 2%) measured by the Nitrogen Flow Method and the Carbon Tetrachloride Method still exist on some columns. No correlation has been found between annular spacing and column performance (see Project No. 19-II); however, column performance is presently being studied in relation to the above-mentioned differences in the two methods.

The data obtained from this and other projects, has brought about the birth of a new one - Project No. 44 - "Investigation of the Reasons for Differences in Column Performance".

Project No. 22 - Examination of Steam and Condensate for Foreign Material, Particularly Hydrogen and Soluble Salts

The installation of the new sampling nozzles in steam and condensate lines has proceeded very slowly and was not completed by the end of the month. A new sampling nozzle and nickel line for S-50 condensate in the K-25 Powerhouse was completed and preliminary results show a much smaller amount of gas from the new line than from the old one. If substantiated, these results are very significant in that they tend to destroy the basis for the original complaint about corrosion due to S-50 condensate.

Considerable thought was given to methods for degassing condensate samples in order to obtain a more accurate result for the gas content, but no conclusions reached.

The possibility of estimating the total corrosion in the entire K-25, S-50 high pressure steam and condensate system by measuring and analyzing the gas pumped from the condensers in the Powerhouse was considered and a few measurements obtained. Nothing conclusive can be reported until further tests have been made.

A contamination of low pressure condensate sufficient to cause the Powerhouse to discard a considerable amount of it was traced to the Cafeteria. After shunting off this condensate, the contamination disappeared.

Project No. 22 - Examination of Steam and Condensate for Foreign Material, Particularly Hydrogen and Soluble Salts - Continued

The question of fluorine in our condensate is still under investigation because K-25 occasionally reports small amounts. The question is largely an academic one because fluorine contents many times these reported would not be expected to be harmful, but the presence of even small amounts would indicate a loss of process material that we should know about. Our own experience with the method of determination is that reported results of 0.5 ppm or less are not reliable. Pre-concentration of the sample by evaporation may enable us to obtain more precise results in this low range.

Project No. 23 - Theoretical Investigations

This project has been inactive during the past month. However, it will still be "carried on the books" in the event that certain studies in this category may be undertaken at some future date.

Project No. 24 - Freeze-off and Alarm Systems

The freeze-off coils (No. 1, 2, and end coils) developed last month have been made up in quantities and installed on many circuits. Operations seems to be very well satisfied with their performance. The accidental filling of 120 capsules has been eliminated completely, and the production of many circuits has increased since the installation of the new restrictor coil.

Four cases of failure have been reported, each of which has failed at the same point. It seems as though the brazing of the 5/16" tits to the iron caps requires enough heat to anneal or crystallize the 1/8" nickel tubing at the weld. This is being remedied with the use of a packed joint instead of brazing.

This project will be discontinued until new problems arrive.

Project No. 25 - Effect of Circulation Rate on the Performance of a Circuit

Discontinuation of this project was recommended in last month's report. Further evidence has been found this month that is in agreement with past results; namely, assay drop of feed along the bottom of a circuit is approximately linear. It is also shown that for flows of as low as 3.5 lbs. per hour, 18 hrs per day circulation, and 20 columns in a circuit, the assay drop is merely 1.7 to 2.0 points.

Since other factors, such as differences in column performance, affect production much more than the above flows demonstrate, this project will be discontinued.

Actual average flows throughout the plant range from 7.0 to 15.0 lbs per hour.

Project No. 27 - Identification and Removal of Plug-Forming Materials

The procedure in determining the amount of sediment contained in sediment traps is to first distill off the pound or so of material in the trap, and then wash out the residue first with carbon tetrachloride and then with water. The sediment is then dried and weighed. This sediment is essentially a green powder which appears to be the tetrafluoride of tuballoy. The particle size of this solid material is so small that it was suspected of being carried in the circulation system as a suspension. For this reason, it was decided to take samples of material from the top and bottom of a circuit, treat it in the same manner as the contents of a trap and see how much sediment was obtained. The results indicate that the process material contained approximately 0.2 grams of sediment per pound. Since sediment trap contents have been found to contain up to 0.5 grams, it appears that a good portion of the sediment found in the traps is suspended TF_4 which is caught in the trap when the C-616 is distilled therefrom.

It is felt that the experimental results which have been obtained to date are not sufficiently accurate to draw definite conclusions. In this connection, a new sediment trap has been designed and will soon be made. This trap has a removable cover to permit complete removal of sediment. It also has about five times the settling capacity as that of the type of trap now in use.

Project No. 29-II - Study of Twelve-Column Circuits

Due to the fact that Rack 15 was shut down during the entire month of July, there is nothing new to report on this project at this time.

Project No. 30 - Production Rate vs. Assay on Circuits Composed of Selected Columns

Due to frequent shut-downs on Rack No. 21, there is little progress to report on this project for the past month. Circuit 2-A, containing nine "good" columns, was found to be capable of producing at a rate of 100 gms/col/day at an assay of 1.24; while Circuit 2-B, containing thirteen "poor" columns, could only produce 60 gms/col/day at 1.19 assay. Both circuits are now being milked at "par" assay, and the available data indicate that Circuit 2-A will produce about 120 gms/col/day at par; while Circuit 2-B will produce only about 30.

Project No. 31 - Two-Stage Operation for Increased Production

During the month of July, one side of Rack 6 (using 400 psi steam) was converted to the two-stage system. This was done in order to observe the effect of the lower steam pressure on this type of operation. (The title of this project was changed to include this rack).

Project No. 31 - Two-Stage Operation for Increased Production - Continued

From July 18th to the 24th, the above circuit produced at a rate of 107 gcd at par. The material operating pressure was 1000 psi. This is 91.5% as much as was produced during May and June with 1000 psi steam

From July 25th to the 31st, using 1500 psi material pressure, 109 gcd were produced at par. This is 93.2% of the May-June production. This production figure is about the same as the single-stage method of production with 400 psi steam. However, a number of minor operating difficulties have been encountered. Due to the fact that each side of Rack 6 is operated on different systems, the rack crews have confused the two methods at times and obtained intercolumn circulation. Plans are being prepared to remedy this, and better operation is expected in August.

Project No. 32 - Testing Columns by Separating Systems Other than C-616

With a 40-60 (by volume) helium-carbon dioxide mixture, large separation of the gaseous components has been obtained in columns operating under plant steam and cooling water conditions. This gaseous system is very sensitive to pressure. At about 50 lbs/sq. in. gauge, equilibrium separation factors in the order of 5 are obtained in 4 to 5 days, while at 90 lbs/sq. in. gauge, equilibrium separation factors in the order of 250 are obtained in about the same time.

At the present time emphasis is being placed on improvement of experimental and analytical techniques for the purpose of improving the reproducibility of results. When the test results are satisfactorily reproducible, columns of different separating capacities will be tested to determine what correlation, if any, exists between separative capacity of a given column when using the above gaseous mixture as compared with C-616.

Project No. 33 - Gas Formation from Process Material

There is considerable evidence to indicate that abortive milkings are sometimes caused by the presence of non-condensable gases in the No. 2 "freeze-off" coil on the milking system, due to the fact that these gases prevent a solid plug from forming in the coil. Such milking accidents can be eliminated by the use of a long freeze-off coil - long enough to form a plug while material is flowing through it. In this connection, the results of Project No. 24 show that an 8-foot coil made of 1/16" i.d. nickel tubing is sufficiently long enough for this purpose. It is planned to install such coils on all circuits in the plant.

Analyses of non-condensable gas from the systems show that it is essentially oxygen and nitrogen with lesser amounts of hydrogen fluoride. The oxygen and nitrogen are present in essentially the same proportion as they exist in air, indicating that these constituents come from the air.

Project No. 33 - Gas Formation from Process Material - Continued

It is considered fairly certain that the sources of HF are (1) the raw material and (2) reaction of water and/or water vapor with C-616. Water can get into the system as a result of (1) leaky columns, (2) inadequate conditioning of columns before filling, and (3) capsules containing water vapor when connected to the system for filling.

The amount of HF found in S-50 product and in material taken from the racks has never been greater than that in fresh material, namely about 0.005 to 0.010%. See final report on this project in the Appendix for experimental details and results of HF determinations.

Project No. 34 - Investigation of Methods of Transferring Process Material

Last month, a proposed scheme for emptying and re-filling storage chambers was submitted to the Engineering Department for standardization. This has since been modified slightly for simplicity, although the method is essentially the same.

The latest method has not been tried as yet for a manifold is in the process of being made. However, as soon as steam is available, it will be tried in transfer room No. 5.

Project No. 35 - Effect of Short and Long Non-Circulation Periods On Circuit Performance

Due to lack of steam, there is little to report in the way of results for the past month. Two runs have been completed on Circuit 4, Rack 21. The first was conducted with about 20 hours of circulation per day, whereas the second had only about 9 hours. In each case there were three equal periods of circulation per day, uniformly distributed through the 24 hours. Surprisingly, the results show that the performance of the circuit was essentially the same in both cases. A third run is going to be made with only six hours of circulation per day. Considerably more data are required before definite conclusions can be drawn regarding the effect of circulation time on circuit performance. It is felt that the few data available at present do not warrant literal interpretation.

Project No. 38 - Material Balance

The present material accounting losses are rendered somewhat inaccurate because of inaccuracies in inventory, inaccuracies of scales, failure to report all losses, tendency on the part of operators to minimize losses, and re-cycling of material in containers. It, therefore, becomes very difficult to analyze unaccounted material losses.

Project No. 38 - Material Balance - Continued

However, it can be safely said that this study has made everyone aware of these discrepancies and the results have been very favorable. When this study was started two months ago, the "unaccounted losses" amounted to about 3,000 lbs. per month. The first month's close attention dropped the above figure to 719 lbs. (June) and the month of July was only 100 lbs. Hence, it seems as though the "unaccounted losses" were in reality "book losses". The project will be discontinued until the figure again becomes alarming.

Project No. 39-I - Varying Milking Time with different Restrictor Coils

There are no results to report on this project for the month of July. This is due to continual or frequent shut-downs of racks on which the experimental work is being carried out. It is expected that by the end of August there will be sufficient data available to show whether or not long circuits when milked at slow rates, are equivalent in performance to short circuits which are milked in the usual time of 5-10 seconds

Project No. 39-II - Study of Milking Methods - Improvement of Technique

The effect of poor milking technique on production has been shown in past reports. Many recommendations have been made to Operations and at present a poster is being submitted. Copies should be posted at the milking position of every rack. All circuits that are reported as "chronic low producers" and do not produce what is expected of them (See Project No. 1) are investigated by this department.

Project No. 40 - Best Operating Conditions with 450-Pound Steam

The four circuits of Rack No. 1 were operated at four different material pressures: 700, 1000, 1250, 1500 psi respectively, using 400 psi steam. The circuit operating at 1500 psi material pressure gave about 25% more production than those at the lower pressures for the two-week period.

The other four racks operating at 400 psi steam and 1000 psi material pressure produced 69% of what they produced with 1000 psi steam. When the material pressure was raised to 1500 psi, their production increased to 95% of what they produced with 1000 psi steam. Under these conditions, only 70% of the steam consumption is required to give about 95% of the production with 1000 psi steam.

Although this data is encouraging, we must remember that it covers only a two-week production period. Further confirmation is necessary. An investigation at higher material pressures and lower steam pressures is also warranted.